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(54) Circuit for dual band tuning

(57) A dual band RF tuning circuit (1) has a first impedance element (4) and a second impedance element (5) between an RF input port (2) and an RF output port (3). Tuning is provided by the impedance elements (4,5) to a first RF signal and a switching transistor (9) is connected to the second impedance element (5) to short the second impedance element (5) for tuning to a second RF signal by the first impedance element (4) alone.

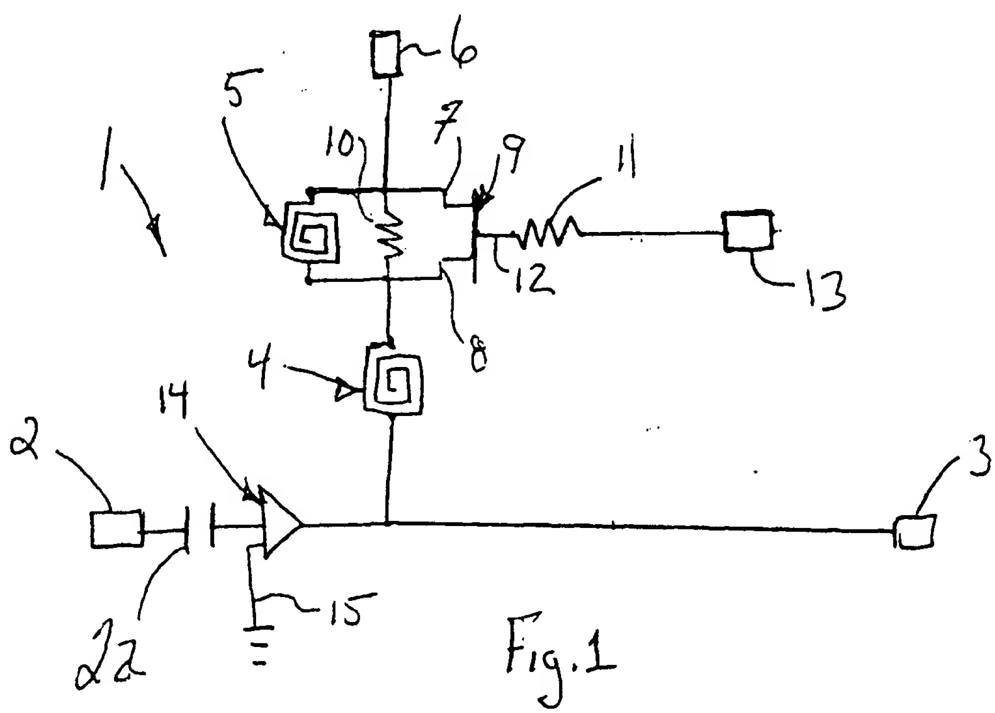

Fig. 1

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Description

[0001] The invention relates to a circuit that is switchable to different frequency bands and to a circuit that is digitally switchable to different frequency bands by changes in reactive circuit elements of the circuit.

[0002] Wireless telephones operate in more than one frequency band, for example, Cellular 900MHz and PCS 1900 MHz. In the past, to operate in more than one frequency band, a separate, narrow band, RF circuit was provided for each of the different bands. The advantage was that each narrow band circuit could be tuned precisely for optimum performance within its tuned frequency band. A disadvantage resided in the relatively large collective sizes of the individual circuits, which restrained the ability to make wireless phones smaller. Further, since the addition of each frequency band required an additional tuned circuit, manufacturing costs were increased. Further, switching among the separate circuits required an external switch, a switch that was external to the RF tuned circuits. An external switch increases manufacturing cost and operates slowly in an external circuit.

[0003] As described in U.S. Patent 3,611,154, a known circuit that is switchable to different frequency bands, for example, UHF and VHF bands, has a local oscillator with a transistor that is biased by a bias voltage applied at a point designated "A" to an LC (inductance, capacitance) resonant circuit connected between the base and collector of the transistor. The resonant circuit is referenced to ground or earth. A varicap diode in the resonant circuit has its capacitance varied by the value of its bias voltage, which allows tuning of the resonant circuit of the local oscillator for resonance with a first frequency band, UHF, for example. To switch to a second frequency band, VHF, for example, a switching diode starts conducting. The switching diode is connected at the junction of two inductors in the LC resonant circuit, and is biased to a conducting state by a switching voltage applied at a point designated "S". There are DC blocking capacitors between earth and the switching diode, such that when a double throw switch is thrown to apply the switching voltage to the diode, the diode is biased to a conducting state, causing current to flow through one of the inductors to ground. Thereby, one of the two inductors becomes shorted to ground, which tunes the resonant circuit for resonance with the second frequency band.

[0004] Disadvantages of the known circuit reside in the double throw switch, which is external to the RF tuned circuit. The RF tuned circuit must be manufactured with the switch as an external component. Further, the switch is slow to operate as it is external to the RF tuned circuit. The known circuit is further disadvantageous as having an ECL biased transistor, which is not suitable for low voltage operation. The double throw switch of the known circuit in the off position is shunted to ground through a resistive load in parallel with a Zener diode, which dissipates current, and which is unsuitable for use in a low voltage device, such as, a dual frequency band, personal communications unit.

[0005] Another known circuit switchable to different frequency bands is described in U.S. Patent 4,379,269. The known circuit has an FET transistor in which one gate is supplied by a bias voltage and a second gate is fed with a uniform voltage by an automatic gain control, AGC. A voltage that is used as the bias voltage is divided at a voltage dividing point. A switching voltage is used to switch to different frequency bands. The switching voltage is supplied to a switching diode. The switching diode conducts and shorts an inductor of a resonant circuit to ground. The switching diode feeds the switching voltage at the voltage dividing point, which raises the voltage at the dividing point upon the reception of a high frequency band. Upon selection of a low band a bias voltage is applied to the switching diode, which back biases the diode. The diode ceases to conduct, and the inductor of the resonant circuit is no longer shorted to ground. At the same time, the bias voltage is applied to a voltage dividing circuit and is impressed as the bias voltage upon the first gate of the FET, which tunes the RF circuit to a lower frequency band. The FET has its AGC delayed if the bias voltage to the first gate is lowered. The FET has its AGC advanced if the bias voltage at the first gate is made higher. A disadvantage of the known circuit is its unsuitability for a low voltage application, such as personal communication devices, because the switching diode is a discrete circuit element requiring significant voltage for its bias, either forward or backward bias. Further, the switching diode is an active device having its own characteristics as a reactive element with capacitance and inductance values that deter the precise tuning of the resonant circuit to different frequency bands.

[0006] The invention relates to dual band matching by either a dual band inductance circuit or a dual band capacitance circuit. The invention allows many of the same circuit elements and functions to be used in different frequency bands without significant performance degradation or increase in size. The invention utilizes matching circuit networks capable of precise tuning to multiple frequency bands. According to an embodiment of the invention, MESFET switches are integral with the tuning circuits, which enables fast switching response and low voltage operation, as opposed to known circuits having external switching devices, such as, a double throw switch and a switching diode, as described by the above referenced patents. The MESFET switched circuits according to the invention are fabricated as part of the tuning circuit, and are of lower inherent impedances than discrete switching devices, which enables precise tuning to multiple frequency bands. The MESFET switched circuit is adaptable for dual band tuning of reactive element tuning circuits, including dual band inductance circuits and dual band capacitance circuits.

Description Of The Drawings

[0007] Embodiments of the invention will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a schematic view of one embodiment of a dual band RF tuning circuit according to the invention;
Figure 2 is a schematic view of another embodiment of a dual band RF tuning circuit; and
Figure 3 is a schematic view of yet another embodiment of a dual band RF tuning circuit.

[0008] With reference to Fig. 1, a dual band RF tuning circuit 1 is in the form of a dual band inductance tuning circuit connected between an RF input port 2 and an RF output port 3. The input port 2 receives an input RF signal of a selected frequency band. The input port includes a DC blocking capacitor 2a. Tuning is provided by a first impedance element 4 in the form of an inductance impedance element having a first inductance L_a and a second impedance element 5 in the form of a second inductance element having a second inductance L_b. The impedance elements 4, 5 are in series connection with a reference voltage port 6 receiving an input, low voltage V_{ref}, for example, 2.7 volts.

[0009] The second impedance element 5 is in parallel connection with two conducting gates 7, 8 of a switching transistor 9, for example a MESFET switching transistor. A relatively large, current blocking resistance 10, for example, 5K Ohms, is in parallel connection with the second impedance element 5. Further, the two conducting gates 7, 8 of the switching transistor 9 are in parallel connection with the resistance 10 that serves as a biasing resistor that maintains the two conducting gates 7, 8 at the same potential. A similar biasing resistor 11 is connected at the gate 12 of the switching transistor 9.

[0010] When the switching transistor 9 is nonconducting, or switched to off, the first and second impedance elements 4. 5 are conducting. The tuning impedance of the circuit 1 is the sum of the first inductance L_a and the second inductance L_b. The circuit 1 is tuned to a first input RF signal at a first bandwidth and the RF signal of the first bandwidth is provided at the RF output port 3.

[0011] The switching transistor is biased on and off, conducting and nonconducting,by changing its bias voltage. The conducting gates 7, 8 of the switching transistor 9 are connected to the second impedance element 5 to short the second impedance element. More specifically, the gate 12 of the switching transistor 9 is biased by a band control voltage source 13 that supplies a band control voltage V_{dd} through the biasing resistor 11 at the gate 12 of the switching transistor 9, causing the switching transistor 9 to conduct and short, or bypass, the second inductance impedance element 5. Accordingly, with the switching transistor 9 conducting, or switched to "on", by the band control voltage, the tuning impedance of the circuit 1 is due to the first impedance element 4 alone. The circuit 1 is tuned to a second input RF signal at a second bandwidth, and the second RF signal is passed by the conducting swithing transistor 9 and is provided at the RF output port 3.

[0012] Further, for example, the input RF signal is supplied first to an amplifier 14 at the RF input port 2. The amplifier 14 is referenced to ground at 15 in a manner to be described in conjuction with Fig. 3.

[0013] With reference to Fig. 2, another embodiment of the dual band RF tuning circuit 1, in the form of a dual band capacitance tuning circuit, will now be described. The circuit 1, of Fig. 2, comprises a first impedance element 4 in the form of a capacitance impedance element of capacitance C_a between the input port 2 and the output port 3. A second impedance element 5, comprises series connected, two capacitance impedance elements 5a, each having capacitances C_b. The second capacitance impedance element 5, of Fig. 2, is in parallel connection with the first capacitance impedance element 4.

[0014] The current blocking resistance 10 of Fig. 2, is provided by a voltage divider having two biasing resistors 10a connected at a voltage dividing point 17. Each biasing resistor 10a has a resistance value of 5K Ohms, for example. The band control voltage source 13 is connected through a similar resistor 10b to the voltage dividing point 17. The voltage divider is in parallel connection with the conducting gates 7, 8 of the switching transistor 9. The resistors 10a are of equal resistive value to maintain the conducting gates 7, 8 at the same potential. A similar biasing resistor 10c connects at the gate of the switching transistor 9 and is referenced to ground 15.

[0015] The switching transistor 9 of Fig. 2 is connected to the second capacitive impedance element 5, to short the second capacitive impedance element 5. More specifically, the conducting gates 7, 8 of the switching transistor 9 are in series connection with, and between the two capacitance impedance elements 5a of Fig. 2. When the switching transistor 9 is switched on, or conducting, the capacitance of the circuit 1 is the mathematical sum of the first capacitance C_a plus ½ of the capacitance C_b. Accordingly, the circuit 1 is tuned to a first input RF signal at a first bandwidth and the conducting switching transistor 9 passes the first input RF signal to the RF output port 3. The switching transistor 9 is turned off by having the gates biased to the same potential by the band control voltage V_{dd} supplied at a low voltage value, for example 2.7 volts, at the voltage dividing point 17. Turning off the switching transistor 9 means that the switching transistor 9 shorts or bypasses the two capacitance impedance elements 5a that comprise the second capacitance impedance 5, which switches the capacitance of the circuit 1 to the value of the first capacitance C_a. Accordingly, with the switching transistor turned off, or nonconducting, tuning circuit 1 is tuned solely by the first capacitive impedance element 4 alone.

Thereby, the tuning circuit 1 is tuned to an input RF signal at a second bandwidth. For example, the input RF signal is amplified by the amplifier 14.

[0016] With reference to Fig. 3, an embodiment of the amplifier 14 will now be described. An input RF signal is supplied through the DC blocking capacitor 2a to the gate 16 of a MESFET transistor 18. A voltage divider having two similar resistances 19 is connected between the gate 16 and one of the conducting gates 22 of the transistor 18. A broadband RF extractor Balun has an inductor 21 connected to the voltage division point of the voltage divider. The amplifier 1 is referenced to ground 15 at the division point of the voltage divider.

[0017] With further reference to Fig. 3, the output of the amplifier 14 is supplied to the input side of the RF tuning circuit 1 that comprises either the inductive tuning circuit, as described and shown in Fig. 1, or the capacitive tuning circuit, as described and shown in Fig. 2. Further, the RF signal is supplied, according to another embodiment, to both of the tuning circuits 1 simultaneously, as in Fig. 3, to provide even greater precise tuning by both an inductive tuning circuit and a capacitive tuning circuit. Not only is there redundancy should one circuit 1 become inoperative but, also, both tuning circuits 1 are operative simultaneously to compensate for stray capacitance and/or stray inductance from external sources of RF signal interference.

[0018] With further reference to Fig. 3, the second inductance impedance element 5 is in parallel connection with a further capacitance 20 to obtain a larger effective inductance.

[0019] The switching transistor 9 has a negligible impedance, permitting precise tuning of each embodiment of the tuning circuit 1 to the optimal narrow band performance. The embodiments of the tuning circuit 1 respectively maintain their DC characteristics of each inductor and capacitor, which avoid adverse impact on the biasing of external active devices in RF circuits. Further, the switching transistor 9 is switched with a low voltage, adapting the embodiments of the tuning circuit 1 for low voltage operation. Further, the switching transistor 9 is digitally switched with quick response to change the RF tuning band. Further, the switching transistor 9 is integrated into each embodiment of the tuning circuit 1, as a single integrated circuit, MMIC, avoiding a requirement for an external discrete device to do the switching. Further, the switching transistor 9, as well as its biasing resistors and the other reactive circuit elements of each of the tuning circuits, are readily fabricated in small sizes when fabricated on an MMIC as a single unit. The combined ability to change inductance and capacitance, the preservation of low voltage DC switching operation, and the simplicity and small size of the invention enables fabrication of a multiple band RF switching device in a single MMIC.

Claims

1. A dual band RF tuning circuit (1) characterized by:

   a first impedance element (4) and a second impedance element (5) between an RF input port (2) and an RF output port (3),
   the tuning circuit being tuned by the first and second impedance elements (4,5) to receive a first RF signal and to provide the first RF signal at the output port (3),
   the tuning circuit (1) being tuned by the first impedance element (4) alone to receive a second RF signal and to provide the second RF signal at the output port (3),
   a switching transistor (9) which is switched on and off by changing its bias voltage, and
   a band control voltage source (13) connected to the switching transistor (9) to change its bias voltage,
   the switching transistor having conducting gates connected to the second impedance element to short the second impedance element, which tunes the tuning circuit by the first impedance element.

2. A dual band RF tuning circuit as recited in claim 1, characterized in that the first and second impedance elements are inductance impedance elements.

3. A dual band RF tuning circuit as recited in claim 1, characterized in that the first and second impedance elements are capacitance impedance elements.

4. A dual band RF tuning circuit as recited in claim 1, and further characterized by conducting drain and source nodes (7,8) of the switching transistor (9) being in parallel connection with the second impedance element (5) to open circuit the second impedance element (5).

5. A dual band RF tuning circuit as recited in claim 4, characterized in that the first and second impedance elements (4,5) are inductance impedance elements.

6. A dual band RF tuning circuit as recited in claim 1, and further characterized by a resistance (10, 10a) connected across the conducting gates of the switching transistor, the source (13) of band control voltage (Vdd) being connected to the dividing point of the resistance, and the conducting drain and the source nodes (7,8) of the switching transistor being in series connection with the second impedance element to open-circuit the second impedance element (5).

7. A dual band RF tuning circuit as recited in claim 6, characterized in that the first and second impedance elements (4,5) are capacitance impedance elements (4,5a,5a).

8. A dual band RF tuning circuit as recited in claim 6 or 7, characterized in that the voltage divider has a current blocking resistance (10a,10a) in parallel connection with the conducting drain and source nodes (7,8) of the switching transistor, and the source (13) of band control voltage (Vdd) is connected through a resistor (10b) to a dividing point of the current blocking resistance.

9. A dual band RF tuning circuit characterized by:

a first inductance impedance element (4) and a second inductance impedance element (5) between an RF input port (2)and an RF output port (3),
the tuning circuit being tuned by the first and second inductance impedance elements (4,5) to receive a first RF signal and to provide the first RF signal at the output port (3),
the tuning circuit being tuned by the first inductance impedance element (4) alone to receive a second RF signal and to provide the second RF signal at the output port (3),
a switching transistor (9) which is switched on and off by changing its bias voltage,
a band control voltage source (13) connected to the switching transistor (9) to change its bias voltage,
the switching transistor (9) having conducting drain and source nodes (7,8) connected to the second inductance impedance (5) element to short the second inductance impedance element, which tunes the tuning circuit by the first inductance impedance element,
a first capacitance impedance element (4) and a second capacitance impedance element (5) between the RF input port (2) and the RF output port (3),
the tuning circuit being tuned by the first and second capacitance impedance elements (4,5) to receive a first RF signal and to provide the first RF signal at the output port,
the tuning circuit being tuned by the first capacitance impedance element (4) alone to receive a second RF signal and to provide the second RF signal at the output port (3),
a second switching transistor (9) being switched on and off by changing its bias voltage,
the band control voltage source (13) connected to the second switching transistor (9) to change its bias voltage, and
the second switching transistor having conducting drain and source nodes (7,8) connected to the second capacitance impedance element to short the second capacitance impedance element (5), which tunes the tuning circuit by the first capacitance impedance element.

10. A dual band RF tuning circuit (1) as recited in claim 9, further characterized by a current blocking resistance in parallel connection with the second inductance impedance element (5), and the conducting drain and source nodes (7,8) of the switching transistor (9) being in parallel connection with the second inductance impedance element (5) to short the second inductance impedance element (5).

11. A dual band RF tuning circuit as recited in claim 9, further characterized in that a resistance (10) connected across the conducting gates of the switching transistor, the source (13) of band control voltage (Vdd) is connected to the dividing point (17) of the resistance, and the conducting drain and source nodes of the switching transistor (7,8) are in series connection with the second capacitance impedance element (5) to short the second capacitance impedance element (5).

12. A dual band RF tuning circuit as recited in claim 11, characterized in that the resistance (10) is a current blocking resistance in parallel connection with the conducting drain and source (13) of band control voltage (Vdd) is connected through a resistor (10b) to a dividing point of the current blocking resistance (10).

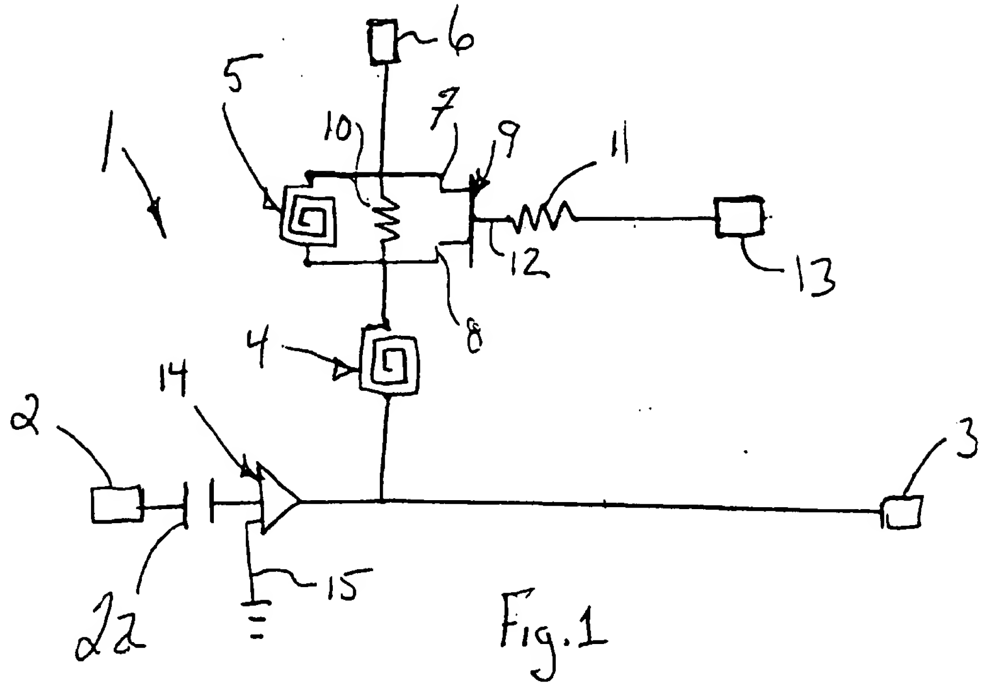
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Fig. 1

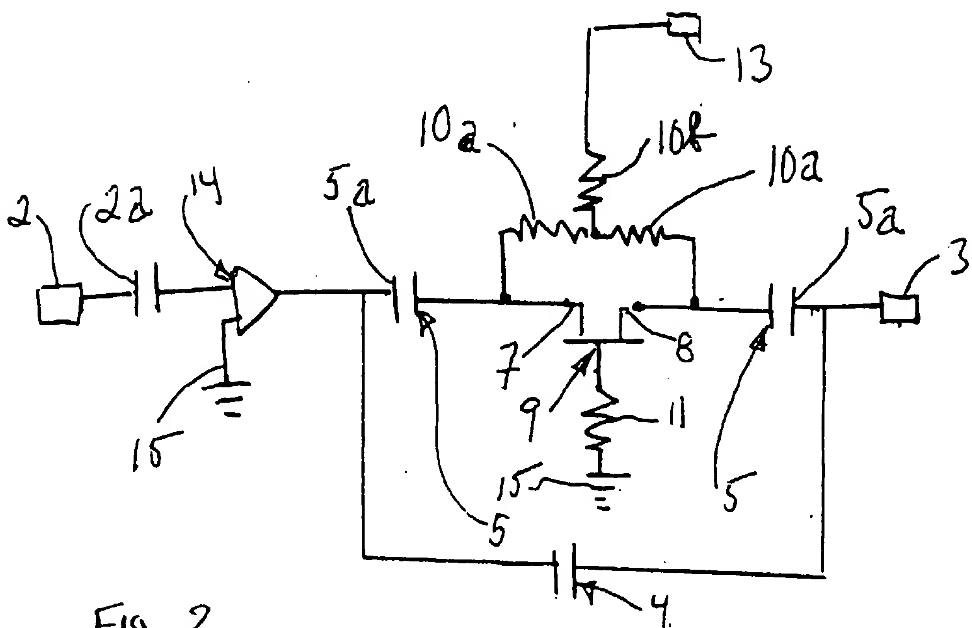
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Fig. 2

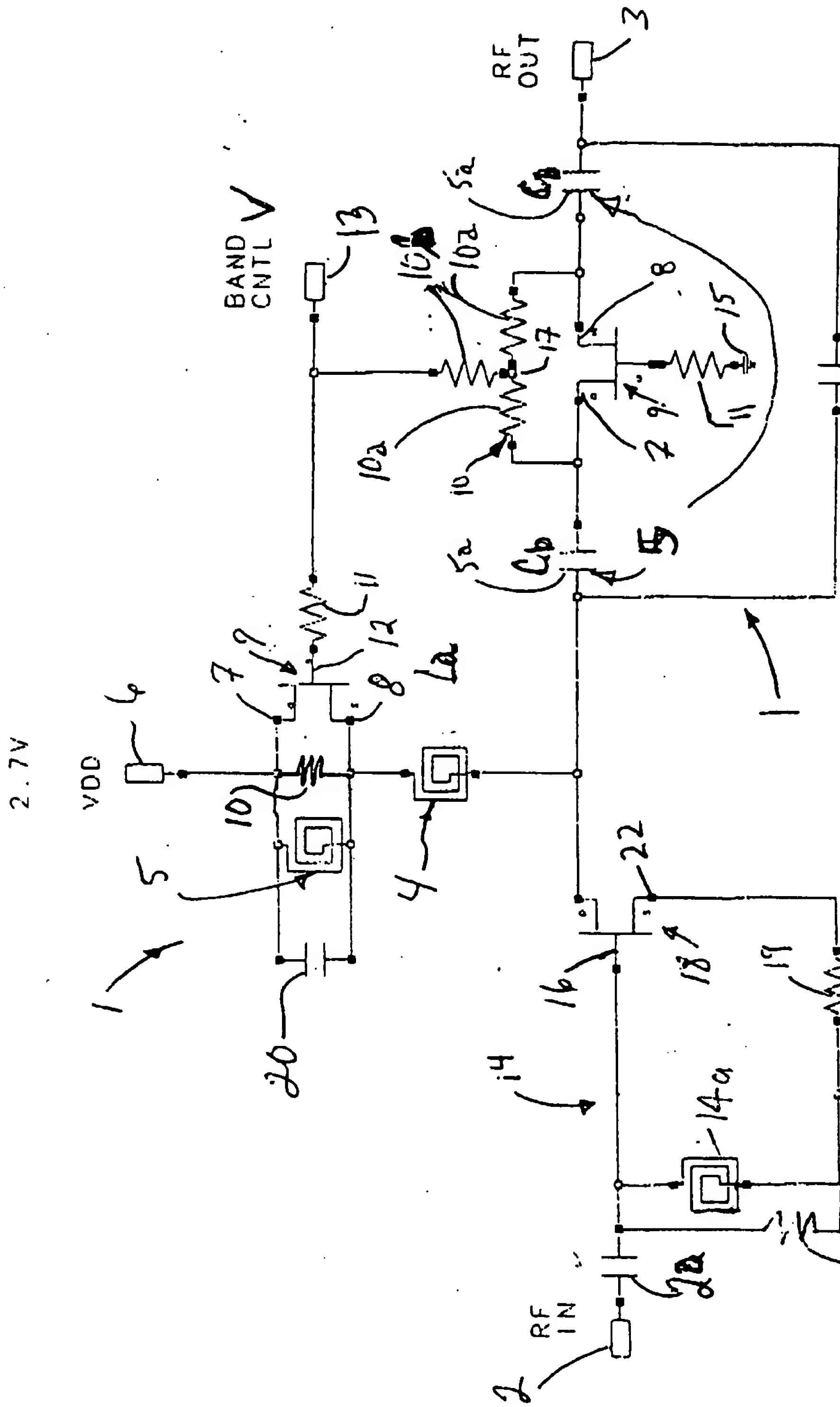

Fig. 3